THE EFFECT OF CALCIUM FERTILIZATION AND CULTIVAR ON YIELD, ELEMENTAL CONCENTRATION OF LEAF AND RIND TISSUE, AND RIND RESILIENCY OF WATERMELON

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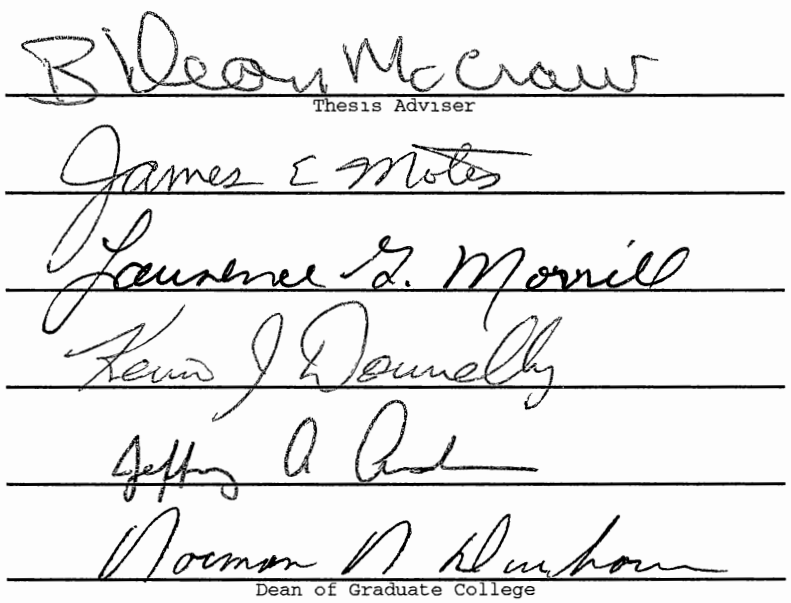

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PREFACE

The purpose of this study was to determine the effect of gypsum fertilization and genotypic response on watermelon [*citrullus lanatus* (Thumb) Matsum and Nakai] yield, fruit quality indices, elemental concentrations of leaf and rind tissue, and rind thickness and resistance to shear and puncture forces. Experiments were conducted at research stations located at Bixby and Stillwater during the 1989 and 1990 growing seasons.

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CHAPTER I

INTRODUCTION

Calcium, the fifth most abundant element in most Oklahoma soils, accounts for more than 3% of the soil composition. The exchangeable Ca content of the average soil ranges from 65 to 85% of its total exchange capacity (Chapman, 1966). The relatively high Ca content of soils and relatively low demand by most plant species imply that mass flow of Ca with the soil solution to the root surface is the predominant transport process in soils (Barber and Ozanne, 1970). Calcium movement to the roots appears to depend more on the transpiration rate of the plant than on root elongation and interception (Bangerth, 1976).

After reaching the interior free space of the root, the suberized casparian strip of endodermal cells prevents further water transport through the apoplast, thereby directing water and ion transport to proceed in the symplast. However symplastic Ca transport is limited, its transport into the stele and xylem occurs where the Casparian strip is not fully developed at the root tip or site of branch root formation (Dumbroff and Pierson, 1971). The question of whether calcium is actively or passively absorbed into the root is not resolved (Bowling, 1973;

Higinbotham et al., 1967). Once located in the stele the Ca ion is transported in the plant almost exclusively in the xylem (Palzkill and Tibbitts, 1977). Translocation of Ca in the plant is accomplished by exchange with negatively charged molecular groups (pectins and lignins) in the xylem (Shear and Faust, 1970; Thomas, 1970). Calcium is nearly immobile in the phloem. Leaf Ca is not mobilized even when deficiencies develop, leading to necrosis in meristems and fruits (Simon, 1978).

Leaves contain considerably more Ca than storage organs or young enclosed tissues from the same plant (Bramlage et al., 1974). Recognizable foliar symptoms of Ca deficiency are seldom observed in field grown fruit or vegetable crops. Despite these facts, serious economic losses occur annually from physiological disorders caused by inadequate levels of Ca. These disorders are believed to be due to an inefficient distribution of Ca from the transpiration stream to growing tissue rather than poor Ca uptake (Kirkby and Pilbean, 1984). Under conditions of limited transpirational pull Ca may become limiting. Two regulatory factors limiting flow of Ca into plant tissue are the external environment and the stage of development of the tissue (Hanger, 1979).

High relative humidity promoted blossom-end rot (BER) in greenhouse grown tomatoes (Bannelos et al., 1985) and Ca shortage in young leaves was linked to reduction in transpiration due to leaf enclosure which subsequently

induces tipburn of lettuce (Tibbitts et al., 1983). Increasing the transpiration rates of growing fruits increases Ca concentration in that tissue more than increasing the calcium supply in the nutrient medium (Marschner, 1983). The rate of xylem flow from the roots to the shoots is determined by root pressure when transpiration is low. Exudation pressure through the xylem is required for Ca transport into non-transpiring leaves or fruits thus avoiding induced Ca deficiency symptoms (Gutteridge et al., 1981; Palzkill and Tibbitts, 1977). Water availability in the rooting medium, particularly during the dark period, is crucial for long distance transport of Ca into organs with low transpiration rates.

A high growth rate of susceptable tissue can contribute to the development of Ca deficiency disorders in fruits (Bangerth, 1979) and leafy tissues (Algera, 1968). The deficiency could be caused by reduced Ca translocation into rapidly expanding storage tissues or by an accelerated rate of cell division, cell expansion, and metabolism. These conditions increase the Ca requirement and render the tissue more susceptible to Ca shortages.

The most important metabolic functions of Ca include its role in membrane stability and maintenance of cell integrity (Epstein, 1972). Membrane stabilization results from the Ca ion bridging the negatively charged groups of the cell wall and membranes. Indeed, many of the visual symptoms associated with inadequate levels of Ca are due to

a general disintegration of membrane structure, resulting in a "leakiness" of the cell (Elkashif and Huber, 1988). The loss of compartmentalization allows the oxidation of polyphenol compounds producing the brown melanin compounds normally found in deficient tissues.

In contrast to K and Mg, Ca activates only a few enzymes, and these are in general membrane bound (Rensing and Cornelius, 1980). This regulation seems to be associated with the ability of Ca to bind to the low molecular weight protein calmodulin. Several key enzymes are activated by calmodulin and, therefore, indirectly controlled by the Ca concentration in the cell. It has also been suggested that calmodulin regulates the transport of Ca in the cell and mediates transfer into the vacuoles (Marmé, 1983).

Calcium deficiency affects fruits, storage roots, tubers and leaf tissues of many plants (Shear, 1975). These physiological disorders, resulting in localized deficiencies of Ca within the plant, appear to occur predominantly in intensive agricultural and horticultural management systems. An increased understanding of the role of Ca in plant nutrition is vitally important, especially under the high input regimes commonly used today.

Growing point disorders, including blackheart of celery (Geraldson, 1954) brownheart of escarole (Maynard et al., 1962), and tipburn of lettuce (Thibodeau and Minotti, 1969), result in death of the growing point and may be followed by

secondary decay. The necrosis appears first at the margins of newly developed leaves and spreads from the growing point with continued growth. Leaves with marginal necrosis may appear at any part of the plant.

Internal tipburn of cabbage is similar to lettuce tipburn as it may result from either a growing point or storage organ type of Ca stress (Maynard et al., 1965; Dickson, 1978). Calcium accumulates in the outer, rapidly transpiring cabbage leaves during the day and in inner head leaves at night (Wiebe et al., 1977). Calcium transport to developing tissue is enhanced by environmental conditions that encourage a high rate of root pressure flow.

Additional physiological disorders have been attributed to inadequate levels of available Ca in developing plant tissue. These include corkspot, watercore, cracking and bitter pit of apples (Dixon et al., 1973; Perring, 1968), hypocotyle necrosis of beans (Shannon et al., 1967), internal browning of Brussels sprouts (Maynard and Barker, 1972), cavity spot and cracking of carrots (Vlach and Vernell, 1961), sprout failure and tipburn of potatoes (Hewitt, 1948), cracking of cherries and prunes (Bullock, 1952; Cline and Tehrani, 1973) and leaf tipburn of strawberries (Mason and Guttridge, 1974).

Blossom-end rot affects the fruits of pepper (Hamilton and Ogle, 1962), tomato (DeKock et al, 1979), and watermelon (Walters and Nettles, 1961b; Cirulli and Ciccarese, 1981). The first symptom of the disorder is a slight water-soaked

discoloration on the blossom-end of the fruit. As the lesions enlarge, they turn leathery and dark brown or black and often become sunken into the fruit. Although the affected tissue is normally dry, bacteria and fungi may invade the lesion, producing a soft, watery rot. The vast majority of the Ca nutrition research has been conducted using tomato as the test crop. Cultivar selection, high soluble salt concentration, intermittent drought, and high rates of potassium and ammonium nitrogen all have a pronounced effect on the Ca status of the plant (DeKock et al., 1979).

Several researchers have investigated the influence of supplemental Ca fertilization on growth and yield of watermelon with variable results (Bradley and Fleming, 1959; Walters and Nettles, 1961a; Elmstrom et al., 1973a). Increasing rates of Ca, supplied as lime, have been shown to decrease (Hartwell and Damon, 1914), increase (Everett et al., 1965; Jones et al., 1975) or not affect (Sundstrom and Carter, 1983) watermelon yield. Quality parameters such as rind thickness, soluble solids and fruit color have also been studied on a limited basis, with variable results (Elmstrom et al., 1973b).

There are many conditions in the field which may contribute to the development of Ca related disorders. Low soil moisture has long been considered an important factor in the development of BER in tomatoes (Pill and Lambeth, 1980). Calcium moves apoplastically through the root's

outer membrane and then in the xylem being pulled along in the transpirational stream. Adequate soil moisture and a healthy root system are necessary for adequate Ca uptake and translocation. Excessive ions in the soil, including NH_4, K and Mg interfere with Ca uptake by the bell pepper (Miller, 1961). Additional factors such as light, variety, and vegetative growth rate can have an impact on the Ca status of the plant (Shear, 1975).

Despite the work that has been conducted in the area of Ca nutrition in watermelon, several discrepancies and unanswered questions remain. The inconsistencies appear in reports on the role of Ca in rind thickness at the blossom-end or the equator of the watermelon fruit (Sundstrom and Carter, 1983), an observation different than that of Walters and Nettles, 1961a. There is also a lack of information concerning the effect of supplemental Ca on developing watermelon fruit and if or how the Ca fraction in the growing tissue changes. The cultivar chosen may impact research results. There is little information on how watermelon fruit shape or seed content may influence Ca levels and quality parameters.

Objectives

1. To evaluate the influence of supplemental Ca (as soil applied gypsum) on yield, soluble solids and flesh redness of watermelon [Citrullus lanatus (Thumb.) Matsum and Nakai].
2. To evaluate the effects of increasing levels of

available soil Ca on the concentration of total and extractable Ca, K, Mg, Zn, Fe and Mn in the fruit rind and leaf tissue.

3. To monitor the elemental concentration of total and extractable Ca, K, Mg, Zn, Fe and Mn in rind tissue based on stage of development of the fruit (days from anthesis) and position of the rind tissue being sampled (stem-end or blossom-end).
4. To determine if rind thickness and resistance to shear and puncture force of mature watermelon fruit are affected by the elemental concentration of the rind tissue being sampled.
5. To evaluate the interaction of cultivar on the same parameters as described in objectives 1-4.

CHAPTER II

SOIL CALCIUM RATES AND CULTIVAR AFFECT ELEMENTAL CONCENTRATION OF WATERMELON LEAF AND RIND TISSUE

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Abstract: A field experiment was conducted to quantify the effect of fertilizer Ca supplied as gypsum in factorial combination with watermelon [Citrullus lanatus (Thumb) Matsum and Nakai] cultivars, 'Charleston Gray', 'Crimson Sweet', and 'Tri-X Seedless', on yield and the elemental concentration of leaf and rind tissue. Also, the effect ontogenetic changes and sectional differences had on the elemental concentration of rind tissue was investigated. The experiments were conducted at 2 locations during the 1989 and 1990 growing season. Yield was not affected by Ca fertilization, however mean melon weight was reduced at the 1120 Ca·kg ha^{-1} rate. Leaf Ca concentration increased linearly in response to Ca rate. 'Tri-X Seedless' had lower leaf Ca concentration and higher K concentration when compared to 'Charleston Gray' or 'Crimson Sweet'. Fruit ontogeny (days from anthesis) and melon section (blossom or stem-end) interacted to affect the elemental concentration in the rind tissue. There was also a significant genotypic response on the elemental concentration in rind tissue. Increasing rates of Ca reduced the incidence of blossom-end rot in 'Charleston Gray' melons. Calcium treatment did not affect flesh redness or soluble solids of watermelon.

Adequate Ca nutrition is essential for normal plant growth and development (Kirkby and Pilbean, 1984). Soil water status, root vigor, relative humidity, wind, high

substrate soluble salt concentration and cultivar selection can affect plant Ca nutrition (Wiersum, 1979). Several Ca deficiency disorders have been described, including blossom-end rot (BER) of pepper, tomato and watermelon (Shear, 1975). These disorders are related more to inefficient partitioning of Ca within the plant than to limited uptake (Bangerth, 1979). Low transpiring organs such as fruits and enclosed tissue tend to accumulate less Ca when compared to leaves from the same plant (Bangerth, 1976).

In field trials, watermelon cultivars with cylindrical or sub-cylindrical fruit generally are highly susceptible to BER while spherical-fruited cultivars are completely or highly resistant (Cirulli, 1974; Cirulli and Ciccarese, 1981).

Studies of the effects of lime on watermelon yield have been conducted with variable results (Bradley and Fleming, 1960; Jones et al., 1975; Lacascio and Lundy, 1962). Increasing rates of Ca, supplied as gypsum ($CaSO_4$) have decreased watermelon yield (Sundstrom and Carter, 1983).

Watermelons grown in sand culture and provided progressively more Ca, supplied as $CaCl_2$, showed increased accumulations of Ca in the leaf and fruit tissue (Walters and Nettles, 1961). Data are not available for Ca accumulation in watermelon fruit grown in field plots or respondant Ca status in developing watermelon rind tissue.

The purpose of this study was to 1) determine if differential soil Ca rates affect the accumulation of Ca in

leaf and rind tissue 2) consider the influence of stage of growth on watermelon fruit Ca status, 3) evaluate phenotypic response of three watermelon cultivars to increasing soil Ca content and 4) determine if increasing soil Ca rates affect the incidence of BER.

Materials and Methods

The field experiments were conducted at the Vegetable Research Station, Bixby, Oklahoma, on a Severn fine sandy loam [coarse-silty, mixed (calcareous), thermic Typic Udifluvents] and Research Nursery and Teaching Arboretum, Stillwater, Oklahoma on a Norge loam [fine-silty, mixed, thermic Udic Paleustolls] during the summers of 1989 and 1990. Nitrogen was incorporated at 34 kg·N ha^{-1} at both locations and plants were sidedressed with 34 kg·N ha^{-1} 4 weeks after transplanting. The top 20 cm of soil at Bixby had a water pH ranging from 6.1 to 6.4 and 5.5 to 5.9 at Stillwater. Soil tests results showed that native levels of P and K were adequate. Black polyethylene mulch (1.2 m wide by 0.38 mm thick) and trickle irrigation hose Bi-wall, (Hardie Irrigation, Luguna Niguel, Cal.) 0.38 mm with holes 30 cm apart were mechanically laid in rows on 5 m centers.

Three week old transplants grown in 100 cm^3 peat pots containing commercial peat-lite mix were in the 3 leaf stage when planted 5 per plot 1.2 m apart. Planting at Bixby and Stillwater was accomplished 6 May and 9 May in 1989 and 19 May and 23 May, respectively in 1990. Soil water potential was maintained between $^{-}20$ to $^{-}30$ kPa with the aid of

tensiometers installed 30 cm deep (Bhella, 1985)

A row-middle incorporated application of 2,6-dinitro-N,N,-dipropyl-(triflouoromethyl)-benzenamine (trifluralin) at 840 $g \cdot ha^{-1}$ was made at time of transplanting. Accepted commercial foliar insecticides were used including, methyl-N-[[(methylamino) carbonyl] oxy]ethanimidethioate (methomyl) and (S)-cyano(3-phenoxyphenyl)methyl-(S)-4-chloroalpha-(1-methyethyl) benzeneacetate (fenvalerate).

Treatments were gypsum, incorporated into a 1.5 m wide band 18 cm deep at 0, 280, 560 & 1120 $kg \cdot Ca\ ha^{-1}$ one week prior to transplanting, in factorial combination with 3 cultivars. The cultivars, chosen to provide a range in susceptibility to BER were, 'Charleston Gray' (highly susceptible), 'Crimson Sweet' (intermediate) and 'Tri-X Seedless' (resistant). The experimental design was a split-split-split-plot, with 3 replications in 1989, and 4 replications in 1990. Gypsum was the main-plot, cultivar the sub-plot, stage of development the sub-sub-plot, and watermelon rind section the sub-sub-sub-plot.

In 1989 and 1990, flowers were tagged at anthesis. One fruit per plot was then sampled at 14 and 21 days and at maturity. Fruit maturity among and between cultivars varied from 30 to 35 days after anthesis. Samples (300 g fresh weight) were taken from the blossom and stem end of 14, 21 days old and mature fruit. Leaf samples consisting of the first fully expanded leaf (lamina and petiole), were taken at anthesis. In 1990 fruit samples were harvested at 10 and

20 days after anthesis and at maturity. Leaf tissue was again collected at anthesis.

Samples were dried at 80°C, ground to pass a 40 mesh screen and stored in air-tight jars. Prior to analysis samples were redried at 80°C for 24 hours. Total Ca was extracted using the ash method (Isaac and Johnson, 1975) and extractable Ca was determined using a 2% acetic acid extraction (Gallaher and Jones, 1976). Standard methods were used for analysis of K, Mg, Zn, Fe and Mn by atomic absorption spectroscopy (Perkin-Elmer, Model 303, Norwalk Conn.).

Marketable watermelons were harvested 4 times at 1 week intervals beginning 31 July in 1989 and 6 August in 1990. The number of fruits, their respective weights, and number of BER affected fruits were determined. A single mature watermelon from each plot was sampled for soluble solids and redness. Color was determined by scanning the placental tissue with a Minolta CR-200 chroma meter. Values of Hunter's L, a and b were taken. Only the 'a' value data (redness) are presented (Francis, 1980). Homogenate from test watermelons was filtered through Whatman no. 6 filter paper and percentage of total soluble solids was measured on a Bausch and Lomb Refractometer, Model No. ABBE-3L equipped with circulating water temperature control at 20C.

Results

Yield responses to treatment influences were not significantly different in 1989 and 1990; therefore, data

are pooled for years. Calcium had no effect on watermelon yield (Table 1). This contrasts with previous reports (Sundstrom and Carter, 1983; Walters and Nettles, 1961). In treatments where Ca was supplied at 1120 $kg \cdot ha^{-1}$ mean melon weight decreased when compared to melons grown at the 560 $kg \cdot ha^{-1}$ and lower rates. All 3 cultivars yielded similarly (Data not shown); however, total yields and mean melon weights were greater in melons cultured at Stillwater than Bixby. Soil pH values within Ca treatments were not influenced by gypsum rate.

Concentrations of total and extractable Ca in watermelon leaf tissue were positively related to soil incorporated Ca (Figure 1). When no Ca was applied 61% of the total Ca fraction (2.11 µg/g), was extractable with 2% acetic acid solution. The extractable Ca fraction remained relatively constant at all Ca rates, ranging from 55 to 61% of the total Ca in the leaf tissue. The acetic acid extraction procedure results in a concentration representative of all plant Ca except that crystallized in Ca oxalate (Gallaher and Jones, 1976).

Genotype significantly influenced the elemental concentration of watermelon leaf tissue (Table 2). 'Charleston Gray' and 'Crimson Sweet' had similar concentrations of total and extractable Ca, but 'Tri-X Seedless' had consistently lower concentrations of both Ca fractions. This trend is reversed for K concentration, with 'Tri-X Seedless' containing higher amounts of K than either

of the other cultivars. These data support previous reports where K and Ca uptake were found to be highly antagonistic (Elmstrom et al., 1973). Concentrations of Mg, Zn, Fe and Mn also varied among cultivars with 'Crimson Sweet' containing a higher concentration than the other 2 cultivars.

In contrast to leaf tissue, rind elemental Ca concentration was not affected by Ca treatment. Total Ca concentrations, in fully expanded leaf tissue ranged from 100% to 500% higher than those of fruit rind tissue (Tables 2 and 3). In general the level of Ca accumulation within watermelon fruit rind tissue was highly variable in relation to Ca rate. However, there was a significant Ca rate and rind section interaction on the accumulation of total and extractable Ca in rind tissue (Table 3).

Watermelon fruit harvested at Stillwater in both 1989 and 1990 demonstrated a significant quadradic response to Ca rate. Total and extractable Ca concentrations in rind tissue sampled from either the blossom or stem-end peaked in response to the 560 $kg \cdot ha^{-1}$ treatment, followed by a distinctive drop at the 1120 $kg \cdot ha^{-1}$ rate (Table 3).

With the exception of Stillwater 1989, the Ca concentration of watermelon rind tissue increased during the first 20 to 21 days of growth and development (Tables 4 and 5). However, imported Ca was partitioned unequally between the stem and blossom-end within the fruit. At 21 days after anthesis the concentration of total Ca, sampled from the

blossom-end of the fruit, began a decline so that rind tissue from mature fruits had a reduced concentration of Ca compared to rind tissue sampled earlier (Table 5).

The Stillwater 1989 data (Table 4) differed in that the total Ca concentration in the blossom-end of the fruit continued to increase. The acetic acid extractable Ca in the rind tissue was more variable than the total Ca. In 1989, the extractable Ca fraction declined steadily in the blossom-end during ontogeny (Table 4). In 1990 the extractable Ca concentrations in both the blossom and stem-end shadowed the response of the total Ca fraction (Table 5).

The elemental concentrations in the stem-end of rind tissue continued to increase during the fruit's development. These data indicate that imported Ca may first be deposited at the stem-end and that transport to the blossom-end may be impeded, at least late in development. This observed gradient in Ca concentration from the stem to blossom-end has been observed in cucumber and hypothesized as Ca depletion from the xylem solution during the transport (Frost and Kretchman, 1989). Tissue from the blossom-end consistently had a reduced total Ca concentration (0.68 to 0.87%, 1989; 0.48 to 0.56%, 1990) compared to concentrations in the stem-end (0.88 to 1.05%, 1989; 0.49 to 0.86%, 1990).

An increase in K during fruit development was observed during both growing seasons and at both locations (Table 4 and 5). Stem-end K concentrations were generally higher

than in the blossom-end. Concentrations of Mg, Zn, Fe and Mn in 1989 (Table 4) differed based on the section being sampled rather than the stage of development of the fruit. Concentrations for most elements were higher during the 1989 season than they were for the 1990 growing season (Tables 6 and 7).

During both the 1989 and 1990 growing seasons, genotypic characteristics had a significant impact on the elemental concentration in watermelon rind tissue (Table 6 and 7). For both years and locations the Ca concentrations for 'Charleston Gray' and 'Crimson sweet' were not significantly different; however, 'Tri-X Seedless' exhibited the lowest Ca accumulation. This trend held true for the extractable Ca fraction also. In addition to 'Tri-X Seedless' rind tissue samples having a lower total Ca concentration, this cultivar consistently had a smaller percentage of the total Ca in the extractable fraction. In the 1989 growing season (Table 6) 37% of the total Ca fraction in 'Tri-X Seedless' was extractable Ca. For 'Charleston Gray' and 'Crimson sweet' the extractable Ca fraction constituted 45% of the total Ca.

Tissue K concentration differed among the 3 cultivars studied (except at Stillwater in 1989), with 'Tri-X Seedless' and 'Crimson Sweet' maintaining higher concentrations compared to 'Charleston Gray' (Tables 6 and 7). With few exceptions Mg, Zn, Fe and Mn concentrations were not significantly different among cultivars.

The effect of fertilizer treatment on watermelon flesh redness and soluble solids was studied. Mean red flesh Hunter 'a' color values ranged from 19.8 to 24.9, and were not significantly influenced by Ca fertilization or cultivar. Fruit heart tissue soluble solids values fluctuated from 9.1 to 11.1% independent of treatment effects.

Blossom-end rot is a physiological disorder of watermelon commonly attributed to inadequate Ca concentrations in the affected tissue (Foroughi and Kloke, 1974; Walters and Nettles, 1961). Increasing rates of soil incorporated Ca had a pronounced effect on reducing the incidence of BER in 'Charleston Gray' watermelons (Table 8). Rates of fertilizer Ca at either 560 or 1120 $kg \cdot ha^{-1}$ significantly reduced the number of BER affected fruits compared to the 0 or 280 kg/ha treatments. Only 5 'Crimson Sweet' fruit were affected with BER in both years. The 'Tri-X Seedless' watermelon demonstrated a complete resistance to the disorder.

Discussion

Leaf elemental concentrations for both total and extractable Ca showed a significant response to soil incorporated Ca rates (Figure 1). These data indicate that increasing gypsum levels did increase leaf amounts of Ca. Gypsum is an adequate source of Ca for field mineral nutrition studies of watermelon, in cases where the pH adjusting benefit of lime is not required. The root systems

of melon plants grown with plastic mulch tend to be confined near the surface and within the polyethylene mulch bed (Bhella, 1985). A relatively shallow root system combined with favorable soil moisture and temperature maintained under the mulch resulted in readily available nutrients for root extraction.

Recognizable foliar symptoms of Ca deficiency are seldom observed in field grown fruit or vegetable crops. Calcium becomes limiting due to an inefficient distribution of Ca by the transpirative stream to growing tissue rather than poor Ca uptake (Kirkby and Pilbeam, 1984). As a result of poor Ca allocation and remobilization, Ca concentration in watermelon leaves and fruits were not correlated. These results agree with conclusions drawn from studies conducted on Ca nutrition of cucumber (Engelkes, et al., 1990).

Genotypic response had a significant influence of the accumulation of Ca in watermelon rind tissue (Tables 6 and 7). Differences in resistance of tomato cultivars to blossom-end rot have been shown to be due to differences in efficiency of Ca uptake and accumulation in the fruit or to differences in the Ca concentration in the fruit (Greenleaf and Adams, 1969).

Little data are available from this study to illucidate why these cultivars vary in regard to Ca nutrition. However it should be noted that the 'Tri-X Seedless' fruit consistently had lower concentrations of total and extractable Ca in both leaf and rind tissue when compared to

the other 2 test cultivars. Despite maintaining a lower Ca concentration, 'Tri-X Seedless' demonstrated a complete resistance to BER (Table 8). Further investigation is needed to adequately describe the histological and physiological differences among these cultivars. The incidence of BER in the 'Charleston Gray' melon was not related to the concentration of total Ca in the rind. These findings are in agreement with work conducted previously (Sundstrom and Carter, 1983).

This study indicates that the extractable Ca fraction is useful as a diagnostic tool for predicting the occurrence of BER. Watermelon rind tissue affected with BER tended to have lower extractable Ca concentration when compared to tissue from the same portion of a unaffected melon (data not presented). These findings are highly variable and further investigation is required.

Transport of Ca into the stem-end of watermelon fruit continues to maturity, while accumulation in the blossom-end slows significantly 7-10 days prior to harvest (Tables 4 and 5). This trend may be due to reduced movement of Ca into the blossom-end and/or dilution of the existing concentrations of the elements as the fruit grew. Whatever the cause, all 3 cultivars studied exhibited the same trend.

Cultivar selection and environmental influences all combine to influence the elemental status of plant tissues. This study has clearly shown that the characteristics of the cultivar chosen are nearly as important as external

pressures applied by the environment, at least relative to soil Ca levels (pH not being limiting).

Elemental concentrations in the leaf and rind tissue were significantly influenced by the environment within each year. Accumulation of nearly all elements was greater during the 1989 growing season when compared to 1990 (Tables 6 and 7). In 1989 the watermelons were infected by a severe outbreak of the foliar disease anthracnose (Collectotrichum lagenarium). The disease reduced biomass production which in turn may have concentrated the elements, with the end result being increased elemental concentrations. Precipitation was significantly higher in 1989 than in 1990. Although all plots were maintained at adequate soil moisture levels and monitored using tensiometers, in 1989 the soil profile adjacent to the plots was wetter and this condition may have led to increased uptake of nutrients.

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Table 1. Influence of soil applied gypsum ($CaSO_4$) on the yield of watermelon.[z]

	Bixby		Stillwater	
Calcium rate ($kg \cdot ha^{-1}$)	Yield ($MT \cdot ha^{-1}$)	Melon wt. (kg)	Yield ($MT \cdot ha^{-1}$)	Melon wt. (kg.)
0	34.7	9.06	38.5	10.17
280	31.3	9.18	41.8	10.00
560	35.0	9.56	42.1	10.22
1120	36.6	9.22	40.9	10.14
Linear	NS	NS	NS	NS
Quadratic	NS	*	NS	NS

[z] Means of 2 years, 3 cultivars.
NS, *, **, Nonsignificant (NS) or significant at 5% (*), or 1% (**).

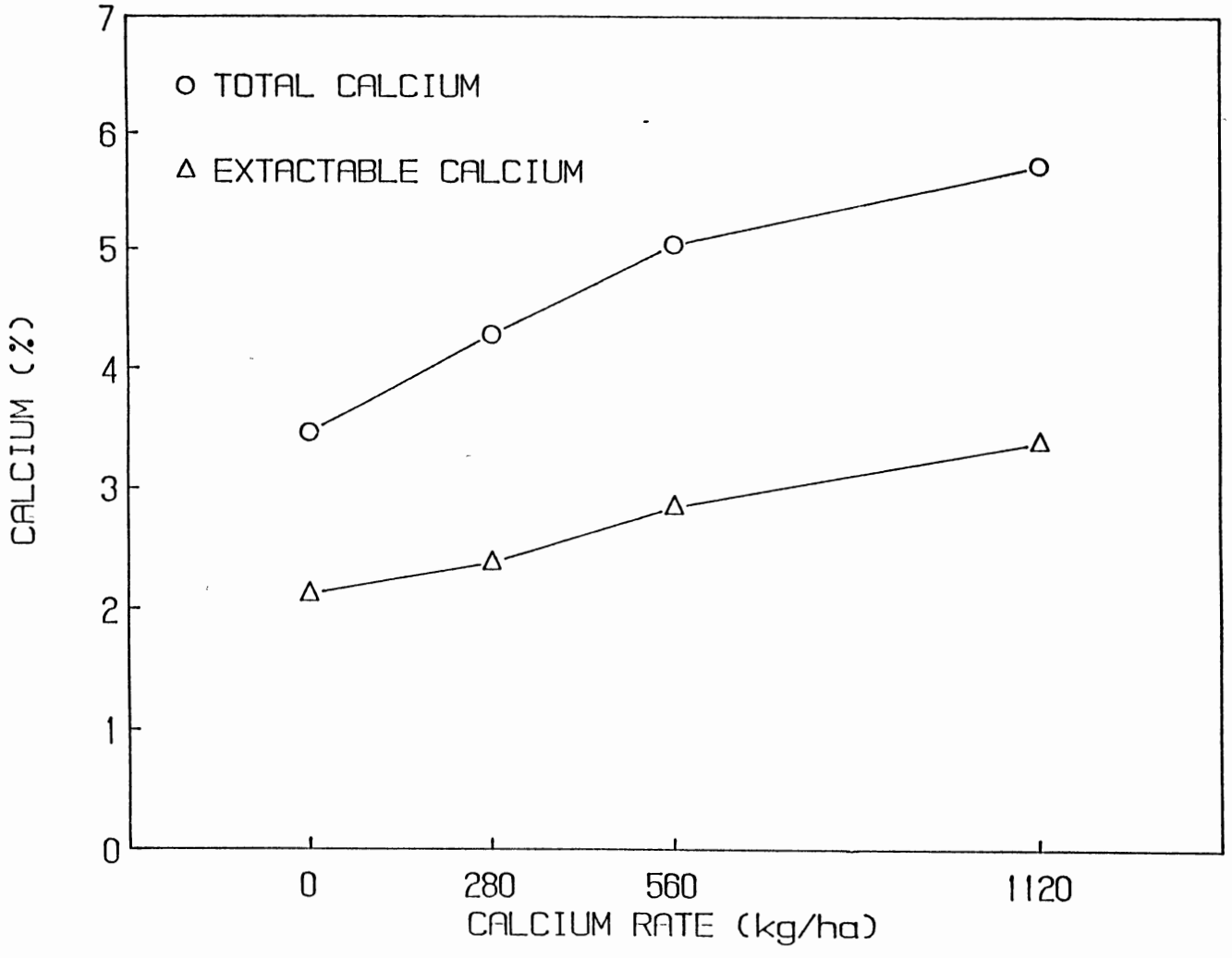

Figure 1. Effect of soil applied Ca ($CaSO_4$) on the concentration of total and extractable calcium in watermelon leaf tissue. Values are means of 2 locations, 3 cultivars and 4 replications (1990).

Table 2. Effect of cultivar on watermelon leaf nutrient concentration[z].

	Nutrient concentration						
	Dry wt (%)				Dry wt (µg/g)		
Cultivar	Total Ca	Ext Ca[y]	K	Mg	Zn	Fe	Mn
Charleston Gray	4.69a	2.72a	1.68b	0.59b	30ab	111b	138b
Crimson Sweet	5.01a	2.91a	1.62b	0.70a	34a	126a	182a
Tri-X Seedless	4.13b	2.40b	2.01a	0.51b	29b	113b	122b

[z] Means of 2 years, 2 locations, 4 Ca treatments. Mean separation in columns by Duncan's multiple range test, 5% level.
[y] Acetic acid extractable fraction.

Table 3. Influence of calcium rate and rind section on the concentration of total and extractable calcium in watermelon rind tissue.[z]

Treatment		Calcium concentration Dry wt (%)							
		Bixby				Stillwater			
Calcium rate	Rind section	1989		1990		1989		1990	
(kg ha^{-1})		Total Ca	Ext. Ca[x]	Total Ca	Ext. Ca	Total Ca	Ext. Ca	Total Ca	Ext. Ca
0	BE[y]	.85	.35	.52	.30	.78	.35	.51	.28
	MT	.98	.42	.48	.30	.60	.25	.44	.31
	MB	1.08	.47	.61	.25	.74	.27	.51	.23
	SE	1.01	.37	.61	.29	.82	.42	.62	.27
280	BE	.76	.31	.51	.29	.81	.39	.54	.28
	MT	.90	.35	.47	.26	.67	.28	.52	.41
	MB	1.05	.45	.58	.22	.79	.29	.69	.27
	SE	.92	.34	.65	.30	.98	.52	.65	.29
560	BE	.70	.27	.55	.30	.85	.42	.55	.32
	MT	1.01	.34	.43	.29	.66	.27	.47	.37
	MB	.93	.44	.60	.21	.74	.28	.57	.24
	SE	.85	.26	.63	.32	.91	.59	.64	.31
1120	BE	.84	.34	.53	.30	.80	.39	.52	.29
	MT	.97	.43	.47	.30	.81	.35	.49	.35
	MB	1.30	.63	.62	.23	.84	.30	.62	.23
	SE	1.00	.36	.67	.32	.83	.57	.63	.28
LSD 0.05									
Section within Ca rate		.12	.1	.11	.04	.06	.06	.09	.03
Ca rate within section									
Linear		NS	NS	NS	NS	NS	NS	NS	NS
Quadratic		NS	*	NS	NS	*	*	*	*

[z] Values mean of 3 cultivars and 4 Ca rates.
[y] BE=Blossom-end MT=Middle top MB=Middle Bottom SE=Stem-end.
NS, *, **, Nonsignificant (NS) or significant at 5% (*) or 1% (*).
[x] Acetic acid extractable Ca.

Table 4. Influence of sampling time and section on the elemental concentration of watermelon rind (1989).[z]

Treatment		Elemental concentration													
		Bixby							Stillwater						
		Dry wt (%)				Dry wt (µg/g)			Dry wt (%)				Dry wt (µg/g)		
Sample time	Rind section	Total Ca	Ext. Ca[w]	K	Mg	Zn	Fe	Mn	Total Ca	Ext. Ca	K	Mg	Zn	Fe	Mn
14 days[y]	BE[x]	.68	.38	4.33	.32	30	52	13	.75	.37	4.76	.49	48	55	11
	SE	.88	.34	5.88	.43	49	66	16	.97	.55	5.60	.42	39	65	30
21 days	BE	.87	.27	6.47	.38	37	63	20	.75	.35	6.42	.42	42	43	12
	SE	.91	.28	6.79	.38	42	58	26	.93	.42	5.70	.40	43	53	28
Maturity	BE	.81	.27	6.85	.36	34	58	14	.78	.27	6.72	.39	51	38	10
	SE	1.05	.38	9.34	.44	47	67	25	.94	.45	7.09	.43	46	71	35
LSD 0.05															
Section within time		.11	.1	1.08	.06	23	13	9	.11	.07	.95	.07	10	17	11
Time within section		.12	.09	1.19	NS	NS	NS	NS	NS	.08	.96	NS	NS	NS	NS

[z] Values mean of 3 cultivars and 4 Ca rates.
[y] Days from anthesis.
[x] BE=Blossom-end SE=Stem-end.
[w] Acetic acid extractable Ca.

Table 5. Influence of sampling time and section on the elemental concentration of watermelon rind (1990).[z]

Treatment		Elemental concentration													
		Bixby							Stillwater						
		Dry wt (%)				Dry wt (µg/g)			Dry wt (%)				Dry wt (µg/g)		
Sample time	Rind section	Total Ca	Ext. Ca[w]	K	Mg	Zn	Fe	Mn	Total Ca	Ext. Ca	K	Mg	Zn	Fe	Mn
10 Days[y]	BE[x]	.52	.29	3.62	.21	25	52	7	.48	.26	4.24	.21	21	61	22
	SE	.54	.26	3.49	.20	30	48	15	.49	.27	4.80	.21	29	40	27
20 Days	BE	.54	.32	4.48	.21	26	39	25	.56	.28	5.29	.25	24	58	49
	SE	.67	.34	4.78	.21	28	41	19	.61	.32	5.28	.21	26	36	34
Maturity	BE	.53	.28	4.64	.23	37	40	30	.52	.30	5.94	.25	34	55	44
	SE	.70	.35	5.32	.24	34	46	25	.86	.31	5.81	.25	30	55	31
LSD 0.05															
Section within time		.05	.03	.25	.01	4	6	4	.04	.03	.20	.01	3	4	4
Time within section		.04	NS	.31	.01	NS	7	4	.06	.03	.36	NS	NS	4	5

[z] Values mean of 3 cultivars and 4 Ca rates.
[y] Days from anthesis.
[x] BE=Blossom-end SE=Stem-end.
[w] Acetic acid extractable Ca.

Table 6. Influence of cultivar on the elemental concentration of watermelon rind (1989).[z]

	Elemental concentration													
	Bixby							Stillwater						
	Dry wt (%)				Dry wt (µg/g)			Dry wt (%)				Dry wt (µg/g)		
Cultivar	Total Ca	Ext. Ca[y]	K	Mg	Zn	Fe	Mn	Total Ca	Ext. Ca	K	Mg	Zn	Fe	Mn
Charleston Gray	.95a	.40a	6.84c	.43a	60a	65a	26a	.91a	.44a	5.81a	.43a	51a	57a	26a
Crimson Sweet	.93a	.38a	7.31b	.41a	63a	63a	22a	.83a	.39a	6.24a	.41a	50a	57a	22a
Tri-X Seedless	.83b	.28b	8.00a	.40a	67a	62a	25a	.71b	.29b	6.37a	.40a	42a	50a	17a

[z] Means of 4 Ca rates and 2 sections, mean separation within column and location by Duncan's multiple range test, 5% level.
[y] Acetic acid extractable Ca.

Table 7. Influence of cultivar on the elemental concentration of watermelon rind (1990).[z]

	Elemental concentration													
	Bixby							Stillwater						
	Dry wt (%)				Dry wt (µg/g)			Dry wt (%)				Dry wt (µg/g)		
Cultivar	Total Ca	Ext. Ca[y]	K	Mg	Zn	Fe	Mn	Total Ca	Ext. Ca	K	Mg	Zn	Fe	Mn
Charleston Gray	.62a	.32a	4.23b	.23a	31b	45a	22a	.61a	.33a	4.96c	.25a	30a	54a	37a
Crimson Sweet	.61a	.31a	4.89a	.21a	36a	44a	21a	.58a	.30a	5.49a	.23a	31a	51a	36a
Tri-X Seedless	.49b	.24b	4.67a	.20a	29b	41a	20a	.52b	.26b	5.20b	.22a	23b	46b	33a

[z] Means of 4 Ca rates and 2 sections, mean separation within column and location by Duncan's multiple range test, 5% level.
[y] Acetic acid extractable Ca.

Table 8. Incidence of blossom-end rot in 'Charleston Gray' melons as affected by soil calcium rate (gypsum).[z]

Calcium treatment ($kg \cdot ha^{-1}$)	1989		1990	
	Bixby	Stillwater	Bixby	Stillwater
0	[y]9a	8a	13a	12a
280	6b	11a	11a	11a
560	5b	4b	7b	4b
1120	2c	2b	4c	3b

[z] mean separation within rows and years by Duncan's multiple range test, 5% level.

[y] total number of BER affected fruits harvested from all plots with same soil Ca treatment.

CHAPTER III

THE INFLUENCE OF CALCIUM FERTILIZATION AND CULTIVAR SELECTION ON WATERMELON RIND STRENGTH AND THICKNESS

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Abstract: A field experiment was conducted to quantify the effect of fertilizer Ca supplied as gypsum in factorial combination with watermelon [Citrullus lanatus (Thumb) Matsum and Nakai] cultivars, 'Charleston Gray', Crimson Sweet', and 'Tri-X Seedless', on the resistance of rind tissue to shear and puncture force. Rind tissue from mature watermelon fruit was divided into 4 sections, blossom-end, middle top, ground spot and stem-end. Each section was measured for resistance to shear and puncture force by a Model T-1200-G texture and tenderometer system. Rind thickness was also measured. Calcium rate had no significant effect on the total force required to shear or puncture rind tissue. Genotypic response and/or the position of the watermelon rind being evaluated (blossom verses stem-end) significantly influenced the resistance of the rind tissue to shear or puncture force. The positive relation between rind thickness and resistance of the rind to shear and puncture force was significant.

Absence of external Ca, especially if Ca is removed by chelation, causes increased permeability and leakiness of cells (Harrington et al., 1981). The most important metabolic function of Ca seems to be its coordination ability which can provide reversible cross-links that can respond rapidly to changes in environmental conditions

(Williams, 1976).

Fruit rind thickness is an accepted measure of watermelon resistance to damage from bruising and puncture during transit (Breakiron et al, 1956). Calcium plays an integral role in growth and cell wall stabilization (Hanson, 1984). Increased Ca concentrations in developing watermelon rind tissue might allow development of a stronger rind. Increased Ca rates have increased watermelon rind thickness (Walters and Nettles, 1961) or failed to influence rind thickness or rupture pressure (Sundstrom and Carter, 1983).

The purpose of this study was to determine the effects of genotype and Ca rate on watermelon rind thickness and resistance to shear and puncture force.

Materials and Methods

The experiments were conducted at the Vegetable Research Station, Bixby, Oklahoma, on a Severn fine sandy loam [coarse-silty, mixed (calcareous), Thermic Typic Udifluvents] and Research Nursery and Teaching Arboretum, Stillwater, Oklahoma on a Norge loam [fine-silty, mixed, thermic Udic Paleustolls] during the summers of 1989 and 1990. Nitrogen was incorporated at 34 kg·N ha^{-1} at both locations and plants were sidedressed with 34 kg·N ha^{-1} 4 weeks after transplanting. Soil tests results showed that native levels of P and K were adequate. Black polyethylene mulch (1.2 m wide by 0.38 mm thick) and trickle irrigation hose (Bi-wall™ 0.38 mm with holes 30 cm apart) were laid using a mulch applicator in rows on 5 m centers.

Three week old transplants grown in 100 cm^3 peat pots containing commercial peat-lite mix were in the 3 leaf stage when planted 5 per plot 1.2 m apart. Planting at Bixby and Stillwater was accomplished 6 May and 9 May in 1989 and 19 May and 23 May, respectively in 1990. Soil water potential was maintained between $^{-}20$ to $^{-}30$ kPa with the aid of tensiometers installed 30 cm deep (Bhella, 1985)

A row-middle incorporated application of 2,6-dinitro-N,N,-dipropyl-(triflouoromethyl)-benzenamine (trifluralin) at 840 $g \cdot ha^{-1}$ was made at time of transplanting. Accepted commercial foliar insecticides were used including, methyl-N-[[(methylamino) carbonyl] oxy]ethanimidethioate (methomyl) and (S)-cyano(3-phenoxyphenyl)methyl-(S)-4-chloroalpha-(1-methyethyl) benzeneacetate (fenvalerate).

Treatments were gypsum, incorporated into a 1.5 m wide band 18 cm deep at 0, 280, 560 & 1120 $kg \cdot Ca\ ha^{-1}$, in factorial combination with 3 cultivars. The cultivars were chosen for their susceptibility to BER. They were, 'Charleston Gray', highly susceptible, 'Crimson Sweet', intermediate and 'Tri-X Seedless' resistant to BER. The experimental design was a split-split-split-plot, with 3 replications in 1989, and 4 replications in 1990. Gypsum was the main-plot, cultivar the sub-plot and rind section the sub-sub-plot.

A single mature watermelon fruit was selected from each plot. Optimum maturity was based on days from anthesis, senescence of the tendril closest to the fruit attachment

and yellowing of the ground spot (Corey et al., 1988). Three 8 x 8 cm rind sections were sampled from the blossom-end, middle-top, middle bottom (groundspot), and stem-end, of each of the test fruits.

Resistance of the rind tissue to shear and puncture was measured utilizing a Food Technology Corp. Model T-1200-G texture and tenderometer system. This Instron type apparatus was equipped with a Model CA-1 single blade shear cell or Model P7-1 penetration test set to quantify the total force (kg) required to shear or puncture the rind. After force measurements, samples were dried at 80C, ground to pass the 40 mesh screen and stored in airtight jars. Prior to analysis samples were redried at 80C for 24 hours. Total Ca was extracted using the ash method (Issac and Johnson, 1975) and extractable Ca was determined using a 2% acetic acid extraction procedure (Gallaher and Jones, 1976). Standard methods were used for analysis of K, Mg, Zn, Fe and Mn by atomic absorption spectroscopy (Perkins and Elmer, model 303). Rind thickness was measured utilizing a centimeter scale. All data were analyzed using analysis of variance with trend analysis and protected LSD as appropriate.

Results

Increasing levels of soil incorporated Ca had no significant effect on the total force required to shear or puncture watermelon rind tissue, (data not shown). These results are in agreement with previous work by Sundstrom and

Carter (1983). In 1989, genotypic response had a significant influence on shear force (Table 9).

'Tri-X Seedless' watermelons grown at Bixby, were significantly more resistant to shear force than either 'Charleston Gray' or 'Crimson Sweet' grown at the same location. All 3 cultivars responded similarly to puncture force (Table 9).

The responses of shear and puncture force varied widely based on the position of the melon rind section being sampled (Table 10). The stem-end sections were consistently more resistant to both shear and puncture force, followed by the 2 equatorial sections which responded similarly. The blossom-end rind section demonstrated the least resistance to mechanical force (Table 10). In 1941 Kenny and Porter reported that the blossom-end of watermelon fruit was less durable than the stem-end. A conclusion substantiated by these data.

The thickness of the watermelon rind is highly dependent on the section of the melon being considered (Table 11). The trend is for the rind to be thickest at the stem-end, with a consistent thinning of the rind towards the blossom-end. Genotypic responses interacted significantly with rind section thickness 'Tri-X Seedless' middle and blossom-end sections were thinner than either 'Charleston Gray' or 'Crimson Sweet'. This response was consistent for all years and location except for Bixby, 1990 where the main effect of position was statistically significant.

In the 1990 growing season, both Ca treatment and rind section interacted to affect the total shear force required to rupture the watermelon rind (Table 12). The shear force values increased for the middle section (MT and MB, Bixby; MB, Stillwater) for Ca rates 0 to 560 $kg \cdot ha^{-1}$, followed by a distinctive decline at the 1120 $kg \cdot ha^{-1}$ rate. The BE and SE sections showed no significant differences in resistance to shear or puncture force due to Ca rate.

Rind resiliency of watermelons harvested in 1990 was affected by cultivar and fruit section (Table 13). As with rind thickness, the rind became increasingly more resistant to external shear and puncture forces beginning at the blossom-end and transversing the fruit to the stem-end. In general, the blossom-end of the watermelon fruit sampled required 25 to 30% less total force to rupture the rind. 'Tri-X Seedless' had higher shear force values than 'Charleston Gray'. 'Crimson Sweet' showed similar responses to 'Tri-X Seedless' for the same rind section.

Elemental analysis of the rind samples for Ca, extractable Ca, and K showed significant positive correlations between these selected minerals and the rind properties shear, puncture and thickness. However, in nearly all cases the correlation coefficients were less than 0.1.

Discussion

Genotypic response and/or the position of the watermelon rind being evaluated (blossom verses stem-end)

significantly influenced the resistance of the rind to force applied by either a shear blade or puncture head (Table 1, 2 and 5). The Magness-Taylor fruit tester has been utilized to investigate rind toughness (Spurr and Davis, 1960), and for field evaluation it continues to have considerable usefulness. Instron measurements for fruit firmness offer the advantage of consistent, highly accurate means to quantify small differences between tissue types in cases where the bulky Magness-Taylor would mask treatment effects (Crete et al., 1974).

Although significant, the correlation between rind thickness and rind 'toughness' is very low ($r = 0.25$). 'Tri-X Seedless' rind sections were consistently more resistant to shear and puncture forces when compared to 'Charleston Gray' or 'Crimson Sweet' while measurements of rind thickness showed 'Tri-X Seedless' to be no thicker and in some cases thinner than the other test cultivars (Tables 3 and 5). Rind thickness alone does not indicate that one cultivar will be a better shipping melon than another cultivar. No attempt was made in this study to investigate the histological differences between cultivars. Cell wall thickness of parenchyma cells composing the middle mesocarp of watermelon rinds was identified as one explanation for differences between cultivars (Kenny and Porter, 1991). Other considerations are melon shape and fruit maturity. More investigation is needed to sufficiently answer the question.

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Table 9. Effect of cultivar on rind resistance to shear and puncture force (kg) at 2 locations (1989)[z].

Cultivar	Bixby		Stillwater	
	Shear	Puncture	Shear	Puncture
Charleston Gray	53.6a	16.9a	55.7a	19.6a
Crimson Sweet	53.6a	17.3a	60.6a	18.7a
Tri-X Seedless	59.0b	17.1a	58.9a	18.3a

[z] Values mean of 4 Ca rates and 4 rind sections. Mean separation within location and columns by Duncan's multiple range test, 5% level.

Table 10. Effect of section on watermelon rind resistance to shear and puncture force (kg) at 2 locations (1989)[z].

	Bixby		Stillwater	
Rind section	Shear	Puncture	Shear	Puncture
BE[y]	45.6a	14.3a	50.7a	15.7a
MT	54.4b	17.5b	55.4b	19.9b
MB	56.6b	17.1b	58.2b	18.9b
SE	65.2c	24.9c	68.6c	22.2c

[z] Values mean of 4 Ca rates and 3 cultivars. Mean separation within location and columns by Duncan's multiple range test, 5% level.

[y] BE=Blossom-end MT=Middle top MB=Middle bottom SE=Stem-end.

Table 11. Interaction of cultivar and rind section on watermelon rind thickness.[z]

Cultivar	Rind section	Thickness (cm) 1989 Bixby	1989 Stillwater	1990 Bixby	1990 Stillwater
Charleston Gray	BE[y]	1.0	1.3	1.0	1.0
	MT	1.5	1.7	1.6	1.4
	MB	1.6	1.6	1.4	1.4
	SE	1.9	1.9	1.6	1.8
Crimson Sweet	BE	1.1	1.1	1.0	1.1
	MT	1.3	1.4	1.4	1.6
	MB	1.5	1.8	1.4	1.5
	SE	1.7	2.0	1.7	1.8
Tri-X Seedless	BE	1.0	1.2	1.1	1.1
	MT	1.3	1.3	1.2	1.3
	MB	1.3	1.4	1.1	1.3
	SE	1.3	1.5	1.6	1.5
LSD 0.05					
Section within cv.		0.1	0.1	NS	0.1
Cv. within section		0.2	0.2	NS	0.1

[z] Mean of 4 Ca rates.
[y] BE=Blossom-end MT=Middle top MB=Middle bottom SE=Stem-end.

Table 12. Interaction of calcium treatment and section of watermelon rind to shear force (kg) at 2 locations (1990).[z]

Calcium treatment	Bixby[y]				Stillwater			
	Rind section				Rind section			
($kg \cdot ha^{-1}$)	BE[x]	MT	MB	SE	BE	MT	MB	SE
0	43.6a	52.3b	55.7c	61.6d	55.1a	58.9b	61.6b	74.0c
280	44.5a	53.2b	55.9c	60.3d	53.0a	57.2b	62.5c	71.1d
560	43.3a	55.4b	60.6c	62.6c	60.4a	60.6a	65.5b	75.0c
1120	45.4a	52.2b	56.8c	57.8c	52.2a	55.3b	59.3c	69.9d

[z] Mean separation within rows and location by Duncan's Multiple range test, 5% level.
[y] Interaction of calcium treatment x rind section significant at 1% level.
[x] BE=Blossom end MT=Middle top MB=Middle bottom SE=Stem end.

Table 13. Watermelon rind resistance to shear and puncture force (kg) for watermelon cultivar and rind section (1990).[z]

		Bixby		Stillwater	
Cultivar	Rind section	Shear	Puncture	Shear	Puncture
Charleston Gray	BE[y]	40.4	12.5	48.5	15.0
	MT	58.0	16.7	55.4	18.0
	MB	53.5	16.5	58.9	18.7
	SE	56.8	21.5	69.0	25.6
Crimson Sweet	BE	46.0	11.9	58.2	16.2
	MT	52.7	16.8	57.7	19.9
	MB	57.3	16.3	61.9	19.3
	SE	61.3	19.9	75.2	23.9
Tri-X Seedless	BE	46.1	12.8	58.8	16.6
	MT	53.8	15.9	60.9	19.7
	MB	56.6	15.5	65.7	19.4
	SE	63.1	19.3	73.3	24.1
LSD 0.05					
Section within cv.		4.0	1.7	4.2	1.7
Cv. within section		5.1	NS	6.2	NS

[z] Mean of 4 Ca rates.
[y] BE=Blossom-end MT=Middle top MB=Middle bottom SE=Stem-end.

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